

WHAT IS CLAIMED IS:

1. A production system for processing a workpiece, comprising:

an index system including a plurality of index devices removably mounted
5 on the workpiece at known longitudinally spaced locations therealong, and a
longitudinally extending index member releasably engaged with at least two of the index
devices such that a position and orientation of the index member are fixed relative to the
workpiece by the index devices, the index member having position-indicating features
therealong; and

10 a machine module mounted for longitudinal movement along the index
member and operable to perform an operation, the machine module being operable to
detect the position-indicating features on the index member and thereby determine a
position of the machine module relative to the workpiece.

15 2. The production system of claim 1, wherein the index member has a machine-
readable position-indicating strip mounted therealong, and the machine module includes
a reader for reading the position-indicating strip so as to determine the position of the
machine module relative to the workpiece.

3. The production system of claim 2, wherein the position-indicating strip
comprises an encoder tape.

20 4. The production system of claim 1, wherein each of the index devices has a
machine-readable sensor mounted therein, the sensor in each index device storing
information including an identifier unique to said index device, and wherein the machine
module includes a reader operable to read the identifier stored in the sensor.

25 5. The production system of claim 4, wherein each index device comprises a pin
structured and arranged to be releasably installed in a hole formed through the workpiece.

6. The production system of claim 5, wherein the pin comprises a quick-
disconnect pin.

7. The production system of claim 4, further comprising a controller in communication with the machine module, the controller being programmed with information correlating the identifiers of the index devices with work process information such that the identifier for each index device is associated with a set of work process information pertaining to a zone of the workpiece at which said index device is mounted.

8. The production system of claim 7, wherein the controller is operable to control the machine module to perform at least one work operation on at least one zone of the workpiece based on the work process information stored in the controller for said zone.

9. The production system of claim 7, wherein the machine module comprises a marking device operable to apply markings on the workpiece based on the work process information corresponding to the zone of the workpiece at which the index system is engaged.

10. The production system of claim 1, wherein the index member and the machine module include cooperating drive elements for moving the machine module along the index member.

11. The production system of claim 1, wherein relative movement between the machine module and the workpiece is effected by a drive system independent of the index member.

12. The production system of claim 1, wherein the machine module includes a clamping arrangement for clamping together parts of the workpiece to be joined.

13. The production system of claim 12, wherein the clamping arrangement comprises a frame having opposed, relatively movable clamping members that clamp the parts therebetween.

14. The production system of claim 13, wherein the clamping arrangement comprises an O-frame on which is mounted a drive device for drivingly engaging the index member to drive the machine module therealong.

15. The production system of claim 13, wherein the clamping arrangement comprises an O-frame having a portion that is movable between a closed position and an open position, movement of the movable portion into the open position creating an opening in the O-frame for passage of the workpiece therethrough such that the O-frame can be engaged with and disengaged from the workpiece at any point therealong.

16. The production system of claim 13, wherein the clamping arrangement is mounted on a base that is supported on a floor of a building in which the production system is housed, and wherein the base has a resilient suspension such that the base is supported in a vertically floating manner on the floor.

17. The production system of claim 1, wherein the index member includes a first index arm operable to engage one of the index devices and a second index arm operable to engage another of the index devices such that the position of the index member relative to the workpiece is fixed by the index devices.

18. The production system of claim 17, wherein the first index arm is fixed relative to the index member and the second index arm is adjustable in longitudinal position along the index member.

19. The production system of claim 18, wherein each of the index devices has a machine-readable sensor mounted therein, the sensor in each index device storing information including an identifier unique to said index device, and wherein each index arm includes a reader operable to read the information stored in the index device engaged by the index arm.

20. The production system of claim 1, wherein the index system includes an index support system for supporting the index member, the index support system being operable to allow relative movement between the index member and workpiece prior to engaging the index devices installed in the workpiece, the index support system being operable to lock up after the index system engages the index devices so as to immobilize the index member relative to the workpiece.

21. The production system of claim 20, further comprising a material handling system operable to hold the workpiece and transport the workpiece along a process flow path, and wherein the index support system is supported on the material handling system.

22. The production system of claim 20, wherein the index support system includes a pair of clamp assemblies operable to applying clamping forces to the workpiece from opposite sides thereof.

23. The production system of claim 20, wherein the index support system includes at least one zero-balance support device for supporting the index member and the machine module such that prior to lock-up of the index support system the index member and machine module are vertically movable upward and downward by application of forces substantially less than the weight of the index member and machine module.

24. The production system of claim 23, further comprising a material handling system operable to hold the workpiece and transport the workpiece along a process flow path, and wherein the index support system after lock-up thereof is pulled by the material handling system so as to travel along the process flow path with the workpiece.

25. The production system of claim 24, wherein the index support system comprises a zero-balance device.

26. The production system of claim 1, wherein the machine module comprises a drill mounted on a frame that is traversable along the index member.

27. The production system of claim 26, further comprising an automatic drill changer mounted on the frame and supporting a plurality of drilling tools, the drill changer and drill being cooperative to change a drilling tool held in the drill.

28. The production system of claim 26, further comprising a fastener insertion device mounted on the frame and operable to insert a fastener into a hole drilled in the workpiece by the drill.

29. The production system of claim 28, wherein the frame includes a clamp mechanism operable to clamp together parts of the workpiece to be joined by a fastener.

30. The production system of claim 29, wherein the clamp mechanism is operable to measure a stack-up thickness of the clamped parts through which the fastener must extend to enable selection of a proper length fastener for insertion into the hole in the workpiece.

31. The production system of claim 30, further comprising a fastener supply system having fasteners of differing lengths and diameters, and a controller connected to the fastener supply system and receiving information from the clamping mechanism as to the stack-up thickness of the clamped parts, the controller controlling the fastener supply system so as to cause the fastener supply system to deliver a proper length and diameter fastener to the fastener insertion device for insertion into the hole in the workpiece.

32. The production system of claim 31, wherein the fastener insertion device comprises a riveter for inserting a rivet wire into the hole in the workpiece and upsetting the rivet wire to form a rivet joining the clamped parts together.

33. The production system of claim 32, wherein the fastener supply system comprises a rivet cutter receiving information as to the stack-up thickness of the clamped parts and operable to cut a rivet wire to a proper grip length based on the stack-up thickness and to supply the cut rivet wire to the riveter.

34. The production system of claim 33, wherein the fastener supply system comprises a plurality of rivet cutters each supplied with rivet wire of a different diameter from the other rivet cutter(s), the controller being operable to select one of the rivet cutters based on a specified rivet diameter for a given location of the workpiece.

35. The production system of claim 26, wherein the drill is rotatable about at least one rotation axis for varying a drilling direction along which a hole is drilled in the workpiece.

36. The production system of claim 1, comprising a plurality of index systems each having a different machine module mounted thereon and each being operable to engage and disengage the index devices mounted on the workpiece.

37. The production system of claim 1, wherein the machine module is operable to determine a longitudinal position of the machine module along the index member, the index member engaging a first index device and the machine module engaging a second index device longitudinally spaced from the first index device, and further comprising a controller in communication with the machine module, the machine module sending a signal indicative of the longitudinal position of the machine module to the controller, and the controller being operable to determine a longitudinal growth of the workpiece between the first and second index devices based on the signal from the machine module when the machine module is engaged with the second index device.

38. A production system for processing a workpiece, comprising:
a material handling system operable to hold the workpiece and transport the workpiece along a process flow path;
an index system fixed relative to the workpiece in a known position and orientation with respect thereto; and
an index support system connected with the index system and supporting one or more items used in processing the workpiece, the material handling system moving the workpiece along the process flow path and causing the index support system with the index system to be passively transported along with the workpiece.

39. The production system of claim 38, wherein the index support system comprises a zero-balance device.

40. The production system of claim 38, wherein the index support system comprises a wheeled cart.

41. The production system of claim 38, wherein the index support system includes a spring suspension.

42. The production system of claim 38, wherein the index support system comprises a sliding base that slides along a floor.

43. The production system of claim 42, further comprising a machine supported on the base and connected with the index system, the index system comprising an index member operable to clamp onto a pair of index devices affixed to the workpiece such that the base with the machine thereon is pulled with the workpiece along the process flow path, and the machine being operable to perform one or more work operations on the workpiece as the base and machine move along with the workpiece.

44. The production system of claim 43, wherein the base is operable to slide back and forth between a starting location and an ending location, and the index member is operable to disengage from the index devices when the base reaches the ending location to allow the base to be moved back to the starting location.

45. The production system of claim 42, further comprising a machine supported on the base and connected with the index system, the machine being operable to clamp onto the index system such that the sliding base with the machine thereon is pulled with the workpiece along the process flow path, and the machine being operable to perform one or more work operations on the workpiece as the base and machine move along with the workpiece.

46. The production system of claim 38, wherein the index system comprises a longitudinally extending index member having a machine-readable position-encoded strip extending therealong, and further comprising a machine engaging the index member, the machine being operable to determine a position of the machine relative to the workpiece by reading the position-encoded strip.

47. A production system for processing a workpiece, comprising:
a plurality of index devices removably affixed to the workpiece in known locations thereof, each index device being proximate a different zone of the workpiece, each index device having a machine-readable sensor in which is stored an identifier unique to said index device;

a reader operable to read the identifier stored in the sensor of each index device;

a controller connected with the reader for receiving the identifier therefrom, the controller being preprogrammed with process information for each zone of the workpiece, the process information for each zone being correlated with the identifier stored in the sensor of the index device located proximate said zone, and the controller being operable to retrieve the process information for each zone based on the identifier read by the reader.

48. The production system of claim 47, further comprising a device for converting the retrieved process information into a visual form for use by a worker.

49. The production system of claim 48, wherein the device for converting the retrieved process information into a visual form comprises a marking device operable to apply markings on the workpiece based on the retrieved process information.

50. The production system of claim 49, wherein the marking device comprises an ink device.

51. The production system of claim 49, wherein the marking device is mounted on a 2-axis positioning system that engages a pair of the index devices for fixing a position and orientation of the 2-axis positioning system relative to the workpiece.

52. The production system of claim 48, wherein the device for converting the retrieved process information into a visual form comprises a projector for projecting visual information onto the workpiece based on the retrieved process information.

53. The production system of claim 48, wherein the device for converting the retrieved process information into a visual form comprises a monitor.

54. The production system of claim 48, wherein each index device comprises a pin releasably mounted in a hole formed through the workpiece.

55. A production system for processing a workpiece, comprising:

a plurality of index devices removably affixed to the workpiece in known locations thereof, each index device being proximate a different zone of the workpiece, each index device having a machine-readable sensor in which is stored an identifier unique to said index device;

a reader operable to read the identifier stored in the sensor of each index device;

a controller connected with the reader for receiving the identifier therefrom, the controller being preprogrammed with process information for each zone of the workpiece including information prescribing locations of holes to be drilled in the workpiece, the process information for each zone being correlated with the identifier stored in the sensor of the index device located proximate said zone, and the controller being operable to retrieve the process information for each zone based on the identifier read by the reader; and

a drilling device connected with the controller and operable to be controlled by the controller so as to drill holes in the locations prescribed in the process information for each zone of the workpiece.

56. The production system of claim 55, wherein the drilling device comprises a drilling head mounted in a 2-axis positioning system.

57. The production system of claim 56, wherein the 2-axis positioning system is operable to releasably engage a pair of the index devices affixed to the workpiece so as to fix a position and orientation of the 2-axis positioning system relative to the workpiece.

58. An index device for mounting on a workpiece to be used as a reference feature in manufacturing operations, comprising:

a housing structured and arranged to attach to the workpiece and engage a hole formed in the workpiece so as to locate the index device relative to the workpiece; and

a machine-readable sensor mounted in the housing, the sensor storing an identifier, whereby the identifier can be correlated with the location of the index device on the workpiece.

5 59. The index device of claim 58, wherein the housing has a generally pin-shaped configuration.

60. The index device of claim 58, wherein the housing has a first portion and a second portion that are positioned on opposite sides of the workpiece and are connected together by a shaft passing through the hole in the workpiece.

10 61. The index device of claim 60, wherein each of the first and second portions defines at least one datum surface providing a position reference.

62. The index device of claim 60, wherein the sensor is located in one of the first and second portions, and the other of the portions has a second sensor therein.

63. The index device of claim 58, wherein the housing defines at least X and Y datum surfaces providing X and Y position references.

15 64. The index device of claim 63, wherein the housing further defines a Z datum surface providing a Z position reference.